the abſurdity of thoſe opinions we have all heard repeated thouſands of times, of wool being converted into hair in the Weſt Indies.

From a compariſon of this with other facts I am perfectly ſatisfied that the varieties of this claſs of animals, poſſeſſing very diſtinct qualities inſeparably connected with *breed*, are much greater, and infinitely more diverſified than has hitherto been ſuſpected. The *ſoftneſs* of the Shetland wool is a peculiarity inſeparable from it, inſomuch that in the *coarſeſt* kinds of ſtockings made of this wool, which I have bought as low as four pence a pair, of a ſufficient ſize for the largeſt man, I could undertake to diſtinguiſh them at the firſt *by the feel*, for their ſuperior ſoftneſs even above the fineſt Spaniſh wool.

N°. XVIII.

An eaſy and accurate Method of adjuſting the Glaſſes of Hadley's Quadrant, on Land for the Back-Obſervation, by ROBERT PATTERSON, *in a Letter to* Dr. DAVID RITTENHOUSE, *Preſident of the Society.*

April 18th, 1794.

SIR,

Read April 18, 1794. THERE are few if any inſtruments of modern invention, of more extenſive uſe in the meaſuring of angles, than that invented by our countryman, Mr. Godfry, but which has unjuſtly got the name of Hadley's quadrant.

I have however often regretted, that for want of ſome eaſy and accurate method of adjuſting the glaſſes for the back-obſervation, practicable on land, and applicable to the *comman octant*, this inſtrument was ſtill ſo much limited

limited in its uſe. For when an angle exceeding 90 degrees is to be meaſured, or when an altitude of the ſun, &c. exceeding 45 degrees is to be taken, by means of a reflecting horizontal ſurface, and ſuch caſes frequently occur, then we muſt either have recourſe to the back-obſervation, or to ſome other inſtrument.

In order to remedy, in ſome meaſure, this inconvenience, the ſextant, without any glaſſes for the back-obſervation, has been introduced; but even this inſtrument is incapable of meaſuring an altitude, by means of a reflecting horizontal ſurface, as above, when exceeding 60 degrees; and this will be the caſe with the meridian altitude of the ſun, in moſt parts of the United States, during four months in the year.

Various methods of adjuſting the glaſſes for the back-obſervation, have indeed been propoſed; but theſe are either very inaccurate and troubleſome, or inapplicable to the common octant, and require ſome appendage to the inſtrument, with which but very few have yet been made.

The following method of making this adjuſtment will not, I flatter myſelf, be found liable to any of the above objections.—It may be made on land, in a few minutes, at any time of the day when the ſun ſhines; requires no additional apparatus, but what any perſon may readily make for himſelf; and the adjuſtment may be relied upon as equally accurate with that for the fore-obſervation.

Deſcription of the Neceſſary Apparatus.

Take a piece of plane glaſs (a piece of looking-glaſs will do very well)—take the poliſh off one ſide of it, and cement it, with the rough ſide down, on the flat ſide of the ſegment of a wooden ball. The ball may be about three or four inches in diameter, and the piece of glaſs of about the ſame dimenſions. Or the glaſs may be cement-

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ed to a piece of board, and this board to a three or four pound ſhot, or ſmall hand-granade, when either of theſe may be conveniently had.

Next take a piece of triangular board of about four inches on the ſide, and through this cut a triangular mortice of about two inches on the ſide. Near the corners of this board let there be inſerted three ſmall nails or pieces of wire, to ſerve as feet for it to ſtand on.

Method of making the Adjuſtment, or finding the Quantity of the Index-Error.

At any time when the ſun ſhines, ſet your triangular board on a table, the cill of a window, or any other convenient ſtand expoſed to the ſun, and place the ball with the piece of glaſs, on the triangular mortice; which, touching the ball only in three points, will conſequently keep it ſteady in any poſition. Turn the ball into ſuch a poſition that the plane of the glaſs may be, as nearly as you can judge, parallel to the equator; and then incline this plane, in the direction of the meridian paſſing through the ſun, till the ſun be about 45° above it.

Now take your octant, and by the fore-obſervation, bring one of the limbs of the ſun's image, ſeen by a double reflection from the ſpecula of the inſtrument, exactly into contact with the image of the ſame limb, ſeen by a ſingle reflection from the ſurface of the glaſs plane, and read off the angle pointed out by the index. Immediately turn round your inſtrument, and bring the ſame limbs into contact by the back obſervation. If the angle now pointed out by the index be exactly the ſupplement (to 180°) of the former angle, the horizon-glaſs for the back-obſervation will be truly adjuſted, or exactly at right-angles with the horizon-glaſs for the fore-obſervation: But if theſe two be not equal, then take half their difference, which will be the correction or in-

dex-error for the back-obſervation; ſuppoſing the fore-horizon-glaſs to have been previouſly well adjuſted. This correction will be additive to all angles meaſured by the back-obſervation, when the angle pointed out by the index in the firſt of the above obſervations is greater than the ſupplement of the other, and vice verſa.

For the ſake of greater accuracy, you may repeat theſe obſervations till you have taken two, four, or ſix ſets; obſerving that if in your firſt ſet you begin with the fore-obſervation, as above directed, then in your ſecond ſet you muſt begin with the back-obſervation, and ſo on. A mean of the corrections thus obtained may be taken as the *true* correction of adjuſtment.

I ſhall conclude this paper with the following miſcellaneous remarks, relative to the ſubject.

1. If the arch of exceſs beyond 90° be but ſmall, as in ſome octants is the caſe, then it may be neceſſary to place the index one or two degrees before the 0, on the extra arch, and adjuſt the fore-horizon-glaſs to this poſition of the index. You will thus obtain a greater range for the index in adjuſting the back-horizon-glaſs.

2. When the reflecting glaſs-plane is placed in the poſition above mentioned, viz. at right angles to the plane of the meridian paſſing through the ſun, then the ſun's path in the heavens will, for ſeveral minutes, be very nearly parallel to the ſaid plane; and therefore no ſenſible error is to be apprehended from the increaſe or decreaſe of the ſun's altitude above this plane during the interval between the firſt and ſecond obſervations in the ſame ſet. But even if this ſhould be the caſe, from the glaſs plane being placed conſiderably *out* of the above poſition, yet, by conducting the obſervations as above directed, the ſmall errors ariſing from this ſource will naturally correct one another.

3. When the poliſh is taken off one ſurface of a piece of glaſs, then the image of the ſun, being reflected only

from one ſurface, will appear ſingle and diſtinct; whereas the image reflected from both ſurfaces, will, moſt frequently, appear double or indiſtinct; ariſing from the want of parallelism between the ſurfaces.

4. The image of the ſun ſeen by a ſingle reflection from one ſurface of the glaſs plane, and that ſeen by a double reflection from the ſpecula of the inſtrument, will both appear nearly of the ſame ſhade or degree of brightneſs; and this will ſeldom be ſo intenſe as to require any ſcreen or coloured glaſs to be interpoſed between the eye and the image.

5. In making obſervations with this inſtrument, whether for the purpoſe of adjuſting the glaſſes, or for any other purpoſe, where great accuracy is required, it is neceſſary that the point on the index-ſpeculum from which the firſt reflection is made, that on the horizon-glaſs from which the ſecond reflection is made, and the eye-hole through which the image is viewed, be all in a plane, parallel to the plane of the inſtrument. This will be effected by wrapping a piece of tape, or the like, round the index ſpeculum, leaving only a bare ſtrip of about a quarter of an inch broad, parallel to the plane of the inſtrument, and at the ſame height above it as the eye-hole, and tranſparent part of the horizon-glaſs.

6. The eye-hole is generally made too ſmall. In meaſuring angles on land, as in the practice of ſurveying, (for which purpoſe this inſtrument is much preferable to any other in common uſe,) in taking altitudes at ſea, in meaſuring the angular diſtance of the ſun and moon, but eſpecially of the moon and a ſtar; the eye has generally need of all the light that can be admitted from the object ſeen by direct viſion.—The eye-hole therefore, ſhould, I think, be nearly as large as the ordinary ſize of the pupil of the eye; nor is any inaccuracy, in this caſe, to be apprehended from the line of viſion not being parallel to the plane of the inſtrument; the eye being capable of placing

placing itſelf with great exactneſs oppoſite the *centre* of the eye-hole.

The ſame objection and remedy are applicable to the ſlits in the ſight-vanes, of the common ſurveying inſtruments.

7. Mr. Maſkyline, and others, recommend the ſun itſelf as the beſt object by which to adjuſt the fore-horizon-glaſs.—There is however conſiderable difficulty attending this mode of adjuſtment.—The ſun is too bright to be viewed directly, without a piece of coloured glaſs interpoſed between it and the eye; and even if the eye-piece be furniſhed with ſuch an appendage (which in the common octant is ſeldom the caſe) ſtill the two images will be of very different ſhades; and either the one ſeen by direct viſion will be too bright, or that ſeen by reflection will be too faint for an accurate obſervation of their coincidence or contact.—This difficulty may however be obviated in the following manner.

Every octant is furniſhed with at leaſt two coloured glaſſes, of different ſhades—take the darkeſt of theſe out of its frame, and with a thread faſten it on *behind* the horizon-glaſs, and turn down the other, between this and the index-ſpeculum: The two images of the ſun will thus be generally of the ſame ſhade, or nearly ſo, and the adjuſtment may then be made with the utmoſt eaſe and ſafety to the eye. Or, which is perhaps better.—Place your eye behind the fore-horizon-glaſs, and, looking through this towards the centre of the index ſpeculum, hold the inſtrument in ſuch a poſition as that the line of viſion may be directed to any point in the heavens, &c. at the angular diſtance of 90 degrees from the ſun; and then, the index being placed at 0, two images of the ſun will appear, both by a ſingle reflection, one from the index-ſpeculum, and the other from the back part of the fore-horizon-glaſs; and by bringing theſe images into coincidence or contact, as when you

look directly at the ſun, the adjuſtment may be made, or the index-error found, with great eaſe and exactneſs. If the images of the ſun ſhould be too bright for the eye, one of the coloured glaſſes belonging to the inſtrument may be held before the eye. The two images of the ſun, thus viewed, will appear nearly of the ſame ſhade, ſince the one from the index-ſpeculum, which would otherwiſe appear the brighteſt, will loſe part of its light by paſſing through the horizon-glaſs.

After all, I am of opinion that this adjuſtment may be made with equal accuracy, and much more eaſe, by any well defined object on land, as the edge of a chimney, the roof of a houſe, or the like, at a ſufficient diſtance.

Any one may ſatisfy himſelf that this is the caſe, by repeatedly meaſuring the error of adjuſtment in the common way, viz. by moving the index till he produces an apparent coincidence between the object ſeen directly and by reflection. If a chimney, or the like, be the object viewed, he will ſcarce ever find any of theſe errors to differ from the mean error more than *one minute;* and the difference of ſuch errors, when the ſun is uſed, will not be leſs, but generally greater.

If the diſtance between the index-ſpeculum and the line of direct viſion (viz. a line joining the eye-hole and horizon-glaſs) ſhould not exceed three inches, which it ſeldom does, then the parallax of the inſtrument will not amount to a quarter of a minute, and may therefore be ſafely neglected; provided the object viewed be at the diſtance of two thirds of a mile. If a ſuitable object at ſuch a diſtance cannot be readily found, then you may take one at any given diſtance, and compute the parallax to be allowed for that diſtance, thus—Multiply the conſtant number 95 (the nat. tang. of 1 to rad. $\frac{1}{10}$) by the diſtance, in inches, of the centre of the index-ſpeculum above the line of direct viſion, and dividing the product

product by the distance of the object in yards, the quotient will be the parallax of the instrument, or correction of adjustment, for that distance in minutes. For example, if the height of the index-speculum above the line of vision be three inches, and the distance of the object 150 yards: then $\frac{95\times3}{150} = 1'.9$ will be the error of adjustment. If therefore you place the index so much behind the 0, on the limb of the instrument and then adjust the horizon-glass by an object at the above distance, the adjustment will be true for an object considered as at an infinite distance.

From the above rule it is obvious that much exactness in measuring or estimating the distance of the object you adjust by is not necessary, provided that distance be not very small; for, in the above example, an error in the distance even of 10 yards would have produced an error of no more than about $\frac{1}{10}$ of a minute in computing the parallax of the instrument.

8. In measuring angles by this instrument, when the object seen by direct vision is at no great distance, the parallax of the instrument must be taken into consideration. In such cases it is commonly recommended, previously to adjust the horizon-glass by that object; but this, in the back-observation, would be attended with very great difficulty—it will therefore be best always to keep the back-horizon-glass at the same adjustment, and make the necessary correction, as above directed, for the distance of the object.

I am, Sir, with much esteem

Yours, &c.

ROBERT PATTERSON.

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